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Is language necessary to interpret visual metaphors?

1 Introduction

Metaphor is defined as the experience of one thing in terms of another thing. Since Richards (1936) argued, “Thought is metaphoric and proceeds by comparison and the metaphors of language derive therefrom”, there have been several approaches to consider metaphor as a conceptual phenomenon (Ortony 1979; Lakoff and Johnson 1980). Recent theories of metaphor suggest that metaphor comprehension requires allocation of various cognitive processes and interaction among different modalities. Several studies have argued (Gibbs and Bogdanovich 1999; Walsh 1990; Neisser 1976) that interpretation of some verbal metaphors require mental images that can produce perception-like experiences.

While presenting contemporary theory of metaphors, Lakoff (1993) discussed a class of metaphors that work by mapping one conventional mental image onto another. He called them *image metaphors*. Similarly, Indurkhya (2007) made a distinction between analytic and synthetic metaphors whereby a class of metaphors namely synthetic metaphors evoke vivid mental images. According to him, certain metaphors cannot be interpreted just by analyzing the meaning constituents of the components of the metaphor, but they require synthesizing subjective mental images evoked by the words and phrases occurring in the metaphor. Neisser (1976) suggested that words are embedded in the perceptual schema associated with the (perceptual) experiences [imagery] that share certain implicit characteristics of the direct perception of the corresponding physical environment. In this framework, he argued that imagery plays a significant role in verbal metaphor comprehension. Similarly, Walsh (1990) conducted behavioral experiments to find that noun-noun metaphors are easier to understand, and are considered more apt, when they evoke some appropriate imagery in the readers’ mind. Studies related to gestures and metaphors claim that language is an integration of speech and gesture at the level of the system and of use and a dynamic product of modality specific forms of thought. Thus language and verbal

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DOI 10.1515/9783110548129-004

metaphor is shaped by cognitive processes, such as the flow of attention and foregrounding of information (Muller 2009).

In recent years, brain-imaging studies have further confirmed that brain areas associated with perception, imagery and motor planning are activated during verbal metaphor comprehension. For example, metaphor comprehension studies using visuo-verbal tasks on brain-damaged patients have shown that right-hemisphere-damaged (RHD) subjects tend to choose literal images over metaphorical images compared to normal subjects. RHD subjects' poor performance in the metaphor task is explained as a result of their insensitivity to context, due to visuo-spatial and visuo-perceptual problems, which is well known in RHD patients (Winner and Gardner 1977), and also because of their inability to integrate different representational (visual and verbal) codes (Rinaldi et al. 2004). A significant role of the right hemisphere in perception and integration of various modalities has been established in normal subjects under various experimental conditions (Anaki, Faust, and Kravetz 1998; Faust and Mashal 2007; Arzouan, Goldstein, and Faust 2007; Rapp et al. 2004; Ahrens et. al. 2007; Shibata et. al. 2007). Motivated by these results, some models have proposed that an imagistic or imagery-producing module is needed while comprehending at least some verbal metaphors, if not all (Carston 2010; Indurkhya 2007, 2016). These studies together support the idea that the understanding process of verbal metaphor is mediated by an interaction among different modalities, and, apart from lexical processing, it requires involvement of various other perceptual processes.

If some verbal metaphors evoke mental images for their interpretation, it is interesting to explore the case of visual metaphors. Visual metaphors are visual manifestations of cognitive metaphors (Lakoff and Johnson 1980), where concepts are represented in images (Kennedy 1982; Forceville 1996; Carroll 1994) (see Figure 1b). An intriguing issue is whether visual metaphors evoke verbal and language areas in order to be interpreted. This is the focus of the fMRI study presented here. If metaphors are primarily perceptual, then we expect that there will be little or no activation of language areas for visual metaphors. On the other hand, if we find significant activation in language areas, it will suggest that metaphors are primarily multimodal: information from all different modalities are recruited to make sense of the incongruity posed by a metaphor in order to render it meaningful.

In behavioral experiments on visual metaphors, it is difficult to completely block the role of language because even though the stimulus maybe purely visual, the response required is usually verbal, especially when an interpretation and a list of features are elicited (Indurkhya and Ojha 2013; Van Weelden et al. 2012). However, in an fMRI study, we can image their active brain areas during visual metaphor comprehension without requiring any verbal responses.

We also aim to compare the brain-activation patterns for verbal and visual metaphors with respect to the Left-Hemisphere (LH) and the Right-Hemisphere (RH) dichotomy, and the current debate on the dominating role of the RH in verbal metaphors. It has been hypothesized that the LH is dominant in processing alphabetic languages (Beaumont 1982; Binder et al. 1996; Desmond et al. 1995; Howard et al. 1992), and the RH is specialized for holistic, imagistic and spatial processing (Bryden 1982; Ellis, Young, and Anderson 1988; Jonides et al. 1993; McCarthy et al. 1994). Given that text and images are different modalities, one corresponding to the LH and the other to the RH, it would be instructive to see if metaphors in each of these modalities respect this hemispheric specialization.

2 Objectives and experiment design

The primary objective of this pilot fMRI study is two fold: First, to determine if the conventional language areas are activated during the visual metaphor comprehension task, and, second, to explore the differences and similarities in the brain activation patterns during the verbal and visual metaphor comprehension tasks. In the present study, participants were shown four different kinds of stimuli: (1) Literal sentences, (2) metaphorical sentences, (3) literal images and (4) metaphorical images. In previous studies, different tasks (plausibility judgment, aptness rating, word-relatedness judgment and so on) and kinds of stimuli (conventional and novel metaphor with their familiarity) have produced different results (Kacinik and Chiarello 2007). For instance, novel metaphor such as "the investors were squirrels collecting nuts" and familiar "broken heart" can produce different results in brain activation (Bottini et al. 1994). Similarly, decision of metaphor vs literal meaning such as "Deep: wise vs. lake) can also produce different results (Van Lancker and Kempler 1987). Therefore, we wanted to adopt a methodology that would reduce the effect of task complexity and metaphor kind. To reduce the task complexity, we asked the participants to decide if the given stimulus is literal or metaphorical (Anaki, Faust, and Kravetz 1998; Mashal, Faust, and Handler 2005). This decision task is not as complex as high-level judgment tasks such as deciding meaningfulness (Schmidt, DeBuse and Seger 2007) or plausibility judgment (Bottini et al. 1994). To avoid the familiarity issue (Schmidt and Seger 2009), we used novel metaphors (both visual and verbal). Moreover, all verbal metaphors used were based on semantic incongruity and not syntactic incongruity (for example, semantic: "the young man drank the guitar" vs. syntactic: "the young man slept the guitar") as this factor can also produce differences in the brain activation pattern (Kuperberg et al. 2000).

We acquired brain-imaging data while participants performed the task in all the four conditions, and contrasted them with the baseline rest state for each participant to get significant neural activation pattern for each condition, and used this direct comparison to look into the differences in the activation patterns. In the experiment, if a participant was not sure about a stimulus, she or he was allowed to skip it and move on to the next one. We analyzed only those responses that matched with our previous categorization (literal or metaphor) of the stimuli, which was independently provided by a group of different participants.

2.1 Participants

Seven postgraduate students (Four males and three females; mean age 25.6 years, range 25–27) participated in this pilot study. All participants were fluent in English and all participants were right-handed as assessed by the Edinburgh Handedness survey (Oldfield 1971). The experiment was conducted under a protocol approved by the Ethics committee of the International Institute of Information Technology, Hyderabad. All participants gave their written informed consent before attending the experiment. Participants were paid for their participation.

2.2 Stimulus material

The stimuli were presented in four conditions: (1) Literal verbal, (2) Metaphor verbal, (3) Literal visual and (4) Metaphor visual. We used sixteen copula sentences (A is B) and sixteen images as stimulus material. The material consisted of eight literal sentences (e.g., "A dolphin is an animal."), eight verbal metaphors (e.g., "Education is stairs."), eight literal images (Figure 1 (a)) and eight visual metaphors (Figure 1 (b)). The verbal sentences in 'A is B' format were without any contextual information. The experimental material was selected as follows: We took twenty metaphorical sentences and twenty literal sentences from the work of Shibataa et al., (2007), and asked seven participants to rate the comprehensibility of these sentences on a 1–7 scale. Eight highly-rated metaphorical sentences (mean comprehensibility: 5.7, SD=1.65) and eight literal sentences (Mean comprehensibility: 6.5, SD=1.12) were selected as the experimental stimuli. For visual material, forty images from print advertisements genre (twenty literal images and twenty metaphorical images) were chosen, and the same seven participants were asked to decide if the image was metaphorical or not. Based on the inter-rater agreement score (Kappa=0.85 with $p < 0.001$), eight literal images and eight metaphorical images were selected for the experiment.

Figure 1. (a) literal visual and (b) metaphor visual

2.3 Procedure

Prior to the actual fMRI scanning phase, the participants were briefed about the experiment. They were also given a practice trial, which included two instances each of all the four conditions. After the practice session, the participants were sent to the brain scanner. The scanning phase involved one session with 32 instances of the four conditions (4 blocks). Each block included 8 trials (stimulus and response) from the following four conditions: (1) literal verbal, (2) metaphor verbal, (3) literal visual and (4) metaphor visual. Trials within the blocks were randomized. There was a five-second gap between any two consecutive blocks during which the participants were presented with a white + sign on a black background. Scans of the initial three minutes during the rest state, when participants did not do any task and lied down quietly, were taken as the baseline. The experimental stimuli were presented on a computer screen mounted at the head coil. Participants were asked to look at the sentence or the image and decide if it was metaphorical or literal. They were asked to press one of the two buttons with their right index finger if it was a metaphor and to press the other button with their middle finger if the stimulus was literal. They were also allowed to skip a stimulus if they could not determine the nature of it by pressing a third button with their thumb (during analysis we did not find any such case). The fMRI data was acquired using 3 Tesla Phillips whole-body MRI scanner[1].

1 The 3 Tesla Phillips whole-body scanner collects high-resolution T1-weighted anatomical images and gradient echo-planar T2-weighted images with blood oxygenation level-dependent contract of 16 axial slices. The parameters of the sequence were set as follows: TR=2000 ms, TE=35ms, flip angle=90°, FOV=230×230 mm, matrix=128×128, slice thickness=5mm, slice gap=1mm.

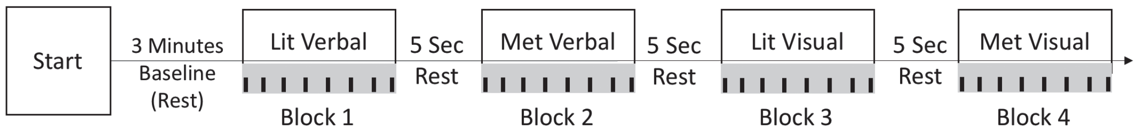

Figure 2. Procedure followed for stimuli presentation

3 Data analysis and results

3.1 fMRI Data Analysis

The data was analyzed using the standard fMRI analysis procedure on SPM[2] software. After initially pre-processing data from each individual participant, a first-level analysis was done by creating four conditions based on the response time, and taking t-contrasts in the SPM in relation to the rest state. The output of this step was contrast images (in relation to the rest state) for individual participants in each of the four conditions. In order to get a generalized result, a second-level analysis of one-sample T testing was done for each condition taking respective contrast images for each participant.

3.2 Behavioral data analysis

We also calculated the mean reaction time for all the responses. The reaction time was defined as the time interval between the onset of the stimulus presentation and pressing of the button by the participant. We found the mean reaction times to be as follows: for literal sentences 2 seconds, for verbal metaphors 2.29 seconds, for literal images 3.25 seconds, and for metaphorical images 4.35 seconds. A one-way ANOVA revealed a significant main effect ($F(3,28)=5.28$, $p<.01$) as shown in Figure 3.

2 Statistical Parametric Mapping (SPM 8, by the members & collaborators of the Welcome Trust Centre for Neuroimaging, UK2). In the preprocessing of data, all functional volumes were realigned to the first volume of each participant to correct for head motion and were spatially normalized and smoothed.

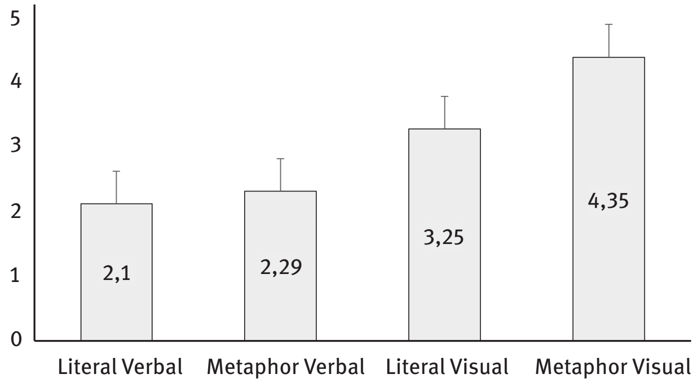

Figure 3. Mean response time in four different experimental conditions

3.3 fMRI results

We contrasted the brain activation patterns for each of the four conditions (literal verbal, literal visual, metaphor verbal, and metaphor visual) with the rest condition, and the results are shown in Table 1. In the **literal verbal** condition, we found activation in *left inferior frontal gyrus*, which is important for processing of syntax in oral and sign languages (Dapretto 1999); *occipital lobe lingual gyrus* and *occipital lobe fusiform gyrus*, both of which are responsible for word recognition and within-category identification (Tan et al. 2000). *Right parietal lobe, precuneus* was also activated, which is involved with episodic memory (Wagner et al. 2005), visuo-spatial processing and aspects of consciousness (Cavanna and Trimbile 2006). For the **metaphor verbal** task, *right temporal sub gyral* was highly activated, which is considered to play a role in auditory processing (Zatorre et al. 1996). We also found high activation in *left caudate,* which is required to monitor and control lexical and language alternatives in production tasks for bilingual individuals (Crinion et al. 2006) and *left middle temporal gyrus*, which is involved in assessing word meaning while reading (Chao, Haxby, and Martin 1999). *Right inferior temporal gyrus*, which is known for the representation of complex object features (Haxby et al. 2001), was highly activated as well. In the **literal visual** condition, significant activations were found in *precuneus*, *right insul*a, *right inferior frontal gyrus*, all of which are involved in sustaining attention and working memory (McAlonan et al. 2007), and *left cingulate gyrus*, which is mostly considered a part of the limbic lobe and is associated with emotional response (Vogt 2005). In the **metaphor visual** task, we found high activation in *left insula* and *left putamen*, which is responsible for reinforcement and implicit and category learning and switching languages (Cincotta and Seger 2007). Significant activation was also found in *right parahippocampal gyrus,* which is considered to be active in scene recognition, memory recall and contextualizing visual background (Medford et al. 2005). It has been suggested that *parahippocampal gyrus* may play a crucial role in identifying social context as well (Chiao et al. 2009), including paralinguistic elements of verbal communication such as sarcasm (Mashal, Faust, and Hendler 2005). There was a significant activation in *left superior temporal gyrus* and *left temporal lobe, sub gyral*, both of which are responsible for language comprehension (Zatorre et al. 1996). *Left temporal lobe* holds the primary auditory cortex, which is important for the processing of semantics in both speech and vision (Friederici et al. 2003). The details of the activation in different brain areas are presented in the appendix 1.

4 Discussion

The objective of this study was two fold: (1) to determine what language areas, if any, are activated during visual metaphor processing; and (2) to explore the neural differences and similarities in visual and verbal metaphor processing. Our results show a significant activation in *left superior temporal gyrus* and *temporal lobe, sub-gyral* (BA 22) while the participants interpreted presented images metaphorically. These include Broca's and Wernicke's areas, and are primarily responsible for auditory perception, speech and language comprehension. We must emphasize here that there was no text embedded in any of the visual-metaphor stimuli. In contrast, we found no significant activity in these areas during the literal-image comprehension. This finding confirms that the comprehension process of visual metaphors requires activation of language areas.

We directly compared the brain activation patterns for the visual and verbal metaphors to explore the differences and similarities between their respective processing, which led to two observations. First, for visual metaphors, we did not find any exclusive right-hemisphere (RH) deployment as has been reported in several verbal metaphor studies (Winner and Gardner 1977; Bottini et al. 1994; Anaki, Faust, and Kravetz 1998), except significant activation in *right Parahippocampal gyrus.* This part of the brain is considered to be involved in detecting sarcasm from non-verbal cues, inferring speaker's intention (Rankin et al. 2009), and in creating internal images and retrieval of visual knowledge (Mashal, Faust, and Handler 2005). Activation in *Parahippocampal gyrus* during visual metaphor comprehension suggests that the incongruity created by juxtaposing two unrelated images triggers similar mechanisms as in sarcasm, and initiates a search for the author's intentions or some other possible context to render the juxtaposition meaningful. It is not surprising that visual knowledge and image-creating mechanisms are involved in visual metaphors.

Secondly, we found some common activation areas for both verbal and visual metaphor conditions. For instance, *sub gyral* was activated in both conditions in the *right frontal lobe,* which is considered to be involved in verbal memory (Shinoura et al. 2011; della Rocchetta et al. 1995). This suggests that verbal memory plays a role both in visual and verbal metaphors. Similarly, *Occipital lobe Precuneus* was significantly activated in both conditions in the left hemisphere. This area is considered to play an important role in visuo-spatial imagery (Simon et al. 2002). Previous studies (Mashal, Faust, and Handler 2005; Bottini et al. 1994) have also shown significant activation in this area for verbal metaphors (especially novel metaphors). Our study adds to this previous research by noting that the left *Occipital lobe Precuneus* is activated in visual metaphor processing too. So we can conclude that visuo-spatial imagery is important to both visual and verbal metaphors.

On the other hand, we found that though *Putamen* was significantly activated in both visual and verbal metaphor conditions, it was in the left hemisphere for visual metaphors, and in the right hemisphere for verbal metaphors. Activation of *right putamen* has been reported in several verbal metaphor studies (Schmidt, DeBuse and Seger 2007). It is suggested that *right putamen* is activated when the reader attempts to construct a unitary coherent model of a discourse and discover the author's intent (Rapp et al. 2004; Kircher et al. 2001; Cooke et al. 2002). Some recent studies focusing on bilingualism have reported activation in *left putamen* when some cognitive control is required such as switching between languages. (Abutalebi et al. 2007; Crinion et al. 2006) and predicting future motor movements (Aramaki et al. 2011). Besides this hemispheric specialization, bilateral activation in *putamen* is reported in tasks requiring implicit or category learning and motor planning and movement. Thus, our findings suggest that interpreting visual metaphors might require some mechanism analogous to switching between languages and predicting future movement. Obviously, this requires further experimentation before a more detailed model can be articulated.

We also found that the response time for visual metaphors was longer than for verbal metaphors. A longer response time usually indicates a more complex mechanism, and vice versa. For example, in research on verbal metaphors, it is argued that the two-stage anomaly model, which assumes that a failure in literal interpretation triggers the search for a metaphorical meaning, would predict a longer response time. Although, several empirical studies have refuted this prediction (Gerrig 1989; Gibbs 1994; Hoffman and Kemper 1987), still recent ERP studies have shown that metaphors appear anomalous at least initially (Tartter et al. 2002), and take longer to comprehend. So a longer response time for visual metaphors suggests a more complex process. However, we leave a more detailed implication of this result for future research on different kinds of visual metaphors with more participants.

5 Conclusion

The main finding of our pilot fMRI study is that language areas are activated during visual metaphor comprehension process. Together with the existing research that has demonstrated that visual imagery areas are activated during verbal metaphor processing, this shows that both verbal and visual metaphors require interaction across different modalities in order to be interpreted: In order to make sense of seemingly anomalous juxtaposition, whether in language or in images, all different modalities, visual, sensory motor, linguistic, and their associated knowledge is brought into play.

Perhaps more significantly, on the basis of previous theoretical studies on visual metaphor, our study provides an initial empirical data on which brain areas are activated during the visual metaphor processing. As most of the existing empirical studies on metaphor are restricted to verbal metaphors, we argue, to develop a more comprehensive cognitive model of metaphor processing, it is crucial that other modalities like visual, aural and gestural are studied as well. The research presented here takes one small step in this direction. In future, we plan to conduct more experiments with more participants with different kinds of visual metaphors. We would also like to explore the interaction between language and images in multimodal pictorial metaphors.

Acknowledgement: We would like to thank Akshita, IIIT-H for her help for organizing the data. This work was supported by the Industrial Strategic Technology Development Program (10044009, Development of a self-improving bidirectional sustainable HRI technology for 95% of successful responses with understanding user's complex emotion and transactional intent through continuous interactions) funded by the Ministry of Knowledge Economy (MKE, Korea) and by the R&D program of the Korea Ministry of Knowledge and Economy (MKE) and the Korea Evaluation Institute of Industrial Technology (KEIT) [10041826, Development of emotional features sensing, diagnostics and distribution s/w platform for measurement of multiple intelligence from young children].

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Appendix

Table 1. Coordinates of activation peaks compared with the Rest state in literal verbal and metaphor verbal conditions as compared to rest condition.

Regions	Side	BA	Coordinates			
Literal Verbal vs. Rest						
			x	*y*	*z*	*t*
Sub-Lobar, Lentiform Neucleus, Putamen	L	–	−30	−4	1	10.13
Insula	R	13	36	20	1	8.97
Frontal-Temporal Space	R	–	48	11	4	7.57
Parietal Lobe, Precuneus	R	07	21	−49	31	6.95
Occipital Lobe, Lingual Gyrus	L	18	−24	−58	4	6.65
Putamen	R	–	21	−4	10	6.01
Inferior Frontal Gyrus	L	47	−24	23	−5	5.56
Occipital Lobe, Fusiform Gyrus	L	20	−30	−58	−11	5.41
Metaphor Verbal vs. Rest						
Temporal Lobe, Sub-Gyral	R	22	33	−52	−2	18.45
Frontal Lobe, Sub-Gyral, White matter	R	–	24	−37	25	17.31
Thalamus	R	–	21	−13	18	15.14
Caudate	L	–	−9	17	10	14.55
Middle Temporal Gyrus	L	39	−39	−58	25	9.97
Claustrum	R	16	30	5	10	8.57
Putamen	R	–	24	17	7	8.48
Inferior Temporal Gyrus	R	20	54	−52	−11	4.50
Occipital Lobe, Precuneus	L	07	−18	−73	19	3.99

Table 2. Coordinates of activation peaks compared with the Rest state in literal visual and metaphor visual conditions as compared to rest condition.

Regions	Side	BA	Coordinates			
Literal Visual vs. Rest						
			x	*y*	*z*	*t*
Precuneus	L	31	0	−46	31	21.28
Insula	R	13	38	−22	−2	18.11
Transverse Temporal Gyrus	R	41	36	−25	10	17.88
Inferior Frontal Gyrus	R	46	42	38	7	9.97
Cingulate Gyrus	L	24	−12	−34	40	9.42

Table 2. (continued)

Literal Visual vs. Rest						
Regions	**Side**	**BA**	**Coordinates**			
			x	*y*	*z*	*t*
Limbic Lobe, Cingulate Gyrus	L	23	0	−25	31	6.72
Midbrain	R	–	12	−22	−14	9.27
Occipital Lobe, Cuneus	L	17	−18	−91	7	7.97
Metaphor Visual vs. Rest						
Putamen	L	–	−21	2	13	9.54
Sub-Lobar, Extra Nuclear, White matter	L	–	−18	−43	22	7.22
Insula	L	13	−36	−25	16	8.20
Frontal Lobe, Sub-Gyral, White matter	R	–	24	−22	40	7.16
Parahippocampal Gyrus	R	27	24	−31	−5	7.03
Superior Temporal Gyrus	L	22	−57	−10	7	6.14
Temporal Lobe, Sub–Gyral	L	22	−42	−34	1	6.06
Occipital Lobe, Precuneus	L	07	−21	−67	19	5.63

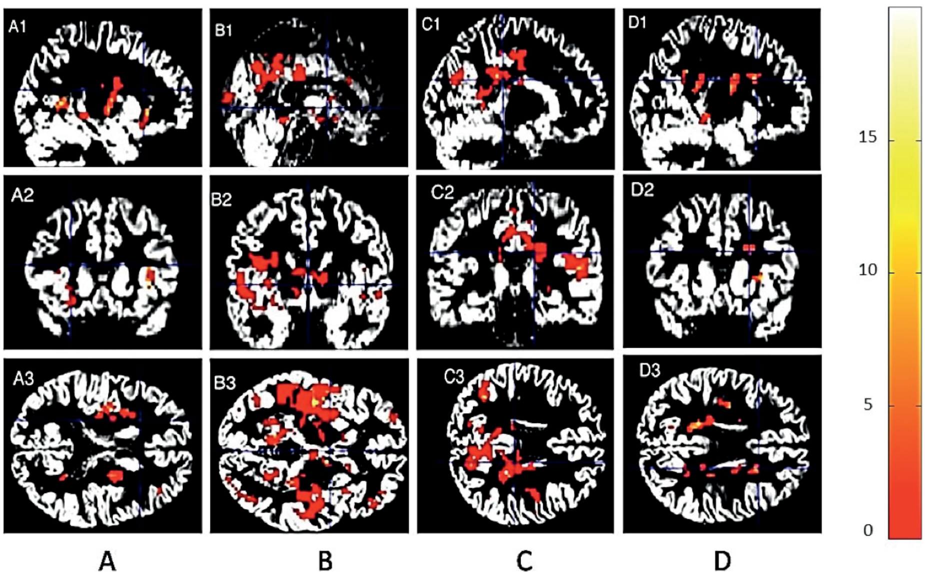

Figure 4. Brain activation elicited by (A) Literal Verbal, (B) Metaphor Verbal, (C) Literal Visual and (D) Metaphor Visual conditions